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FLOW MEASUREMENT

DEVICES AND METHODS

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$$Q = (419A-5)V$$

Q = flow, US gpm

1.0 INTRODUCTION

A common problem encountered by persons dealing with the flow of fluids in pipes or open conduits is the accurate determination of the volumes of such flows.

The basic mathematical formula for the interrelationship of flow parameters is:

$$Q = VA \tag{1}$$

in which

Q = vol. of flow - cubic feet per second

V = velocity of flow - feet per second

A = cross-sectional area - square feet

Devices of various shapes and dimensions have been developed and more or less standardized so that the number of variables can be reduced and flow volume determined on the basis of one measured variable. Various other methods of volume determination may be used by substituting other mathematical values and rearranging the variables of the basic equation.

An outline of the devices and methods suitable for use in determining volumes of wastewater is presented herewith.

2.0 FLOW MEASUREMENT

2.1 Weirs

Weirs are one of the more common flow measurement devices and may be of any one of several shapes (e.g. V-notch, rectangular, Cipolletti, etc.). All require a damming action and a subsequent upstream still-water area which is conducive to silting. For this reason weirs are rejected as a method of wastewater measurement in open conduit and pipes.

2.2 Orifice plates

Like weirs, orifice meters require a flow backup and in addition are prone to clogging by floating solids. They are not, therefore, considered suitable for this application.

2.3 Flow nozzles

Nozzles are essentially orifice plates applied to pressure pipes and therefore have the same disadvantages. They are not considered suitable for use with wastewater.

2.4 Parshall flume

The Parshall flume is a specially constructed measuring flume so designed that the water, for free-flow

conditions, is forced to pass through a critical depth within the structure. This provides a means by which a determination of the amount of water passing can be made from a single depth measurement.

A continuous recording depth gauge is desirable although manual measurements made at frequent intervals may prove adequate under some conditions.

The flume may be constructed in an open channel or in a manhole in a sewer system.

The size of the Parshall flume is designated by the throat width. Flumes in the range of 3, 6, or 9-inch throat are suitable for flows ranging from a minimum of 0.03 cfs (for the 3-inch) to a maximum of 5.7 cfs (for the 9-inch size).

For details of construction and calibration refer to the "Water Measurement Manual", published by the United States Department of the Interior, Bureau of Reclamation.

A Parshall flume with recording depth gauge is accurate, reliable, and not prone to clogging and is therefore recommended as a method of wastewater measurement.

2.5 Commercial meters

Commercial meters, made by a variety of manufacturers and employing a variety of measurement principles are available. These meters, if suited to the conditions in which they are used, are accurate and reliable. For details and advice on specific application, a representative of the manufacturer should be consulted. These meters will normally be the most expensive devices for flow measurement discussed herein. (The approximate cost will be near $2,000). The initial cost must be balanced against future use of the equipment.

2.6 Velocity Measurement

A variety of methods of velocity measurement may be used, and combined with the measured cross-sectional area of flow, introduced into equation 1.

2.6.1 Floats

A weighted cylindrical float, riding partially submerged and in an upright position will provide a close approximation of the average velocity. The use of oranges as floats has also proved effective in practice as their specific gravity is such that they float almost submerged.

2.6.2 Pitot Tube

A pitot tube will provide a measurement of the velocity head, which when inserted in the formula $H - V^2/2g$ will provide a value of V. Pitot tubes are prone to clogging and not recommended for wastewater measurements.

2.6.3 Salt-velocity

The principle of this method is the change in electrical conductivity of water when salt (NaCl) is added. In practice two sets of electrodes are suspended in the flow a measured distance apart and an electrical current applied. A "slug" of salt is applied upstream and will affect the electrical current between the electrodes as it passes.

2.6.4 Salt-dilution

The salt dilution method consists of adding a concentrated salt solution of known strength and by chemical analysis determining its dilution after flowing a distance sufficient to insure complete mixture with the water in the stream.

The analysis of samples, equipment required and quantities of salt required make this a poor method of measurement and its use is not recommended.

2.6.5 Colour velocity

This method consists of introducing a "slug" of dye (fluorescein is recommended) and timing its travel over a measured distance.

2.6.6 Current Meter

A current meter (e.g: the Ott or Gurley) may be used to determine flow velocities. Flow is calculated from the formula

$$Q = (419A-5)V \qquad (2)$$

in which

Q = flow, cfs

A = area, ft_2

V = vel, fps

2.6.7 General

All velocity measurements are applicable to only the flow at the time of measurement, and for a given cross-sectional area. For this reason they must be considered to give only an indication of flow except in steady state conditions. The use of these methods is recommended only as a last resort.

2.7 Calculation

Quantity of flow may be calculated using the formula

$$Q = \frac{1.486}{n} A.R.^{2/3} S^{1/2} \qquad (3)$$

in which

Q = flow - cfs

A = mean area - ft^2

R = mean hyd. radius - ft

S = slope of water surface

= fall/length of course

n = roughness factor

The accuracy of this method is dependent upon the accuracy with which the variables are measured. This, especially in the determination of n, may prove difficult.

2.8 California pipe method

This method of flow measurement (instantaneous, non-recording) is applicable only to pipes flowing less than full and with free horizontal discharge. Flow is calculated by the formula:

$$Q = 8.69\ (1 - {}^{a}/d)^{1.88}\ d.^{2.48} \qquad (4)$$

in which

Q = discharge, cfs

a = distance, in feet, measured in the plane of the end of the pipe, from the top inside surface of the pipe to the water surface.

d = int. pipe diam. - feet.

The formula is accurate for internal pipe diameters from 3 to 10 inches.

This method is not recommended unless no other is available.

3.0 SUMMARY

The foregoing provides an outline of the methods of flow measurement available. The following list is of those methods considered suitable for wastewater flow measurement, in order of desirability (i.e. No.1 is considered most accurate and reliable).

1. Commerical meter, with continuous recording device.
2. Parshall flume, with continuous recording device.

3. Velocity measurement with subsequent calculation.
    a) current meter
    b) float and stop watch
    c) colour velocity and stop watch
    d) salt velocity with galvanometers
4. Calculation (equation 3)
5. California pipe method